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Landscape Ecology Practices in Planning: Landscape Connectivity and Urban Networks

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Abstract

The increasing need to conserve the nature and biodiversity and to maintain human well-being has motivated landscape planners and researchers to seek different planning approaches in urban environments. In this context, different approaches to planning urban networks have been developed to promote the sustainable use and functioning of landscapes, to conserve the nature and species, and increase its use and enjoyment by people [1, 2]. In principle, these approaches have been founded on the conservation of natural areas/biodiversity and with a consensus on their benefits to nature, biodiversity and people [3–5]. However, they generally differ from each other with respect to their expected aims, and ecological and/or social functions [6]. Therefore, by examining different planning approaches to networks, this chapter clarifies what is meant by these concepts and approaches in the literature.

Keywords: landscape planning, landscape ecology, landscape connectivity, sustainable landscapes, urban networks

1. Introduction

Landscape fragmentation affects habitats and wildlife and causes loss of connectivity [7–9]. The detrimental effects of fragmentation can be avoided or minimised by the creation of new habitats and/or the protection of existing habitats by ensuring more connected habitat patches (or the networks of habitats/green and open spaces). Hence, the growing awareness of the need for connected habitats/green and open spaces was reflected in planning approaches such as greenbelts and linked park systems, greenways, ecological networks, green networks and green infrastructure (GI).

These approaches have their own planning aims and strategies, in particular in the early stages of their development. But they have become closer with regard to their common concerns and the underlying concept of landscape connectivity to identify their spatial configuration. In the context of this chapter, the theoretical and scientific background of different network approaches has been reviewed.

The scope of early landscape planning approaches to networks was limited by their foci, where the spatial planning of nature and human dimensions has been treated as separate sectors. However, nature conservation and landscape planning practices have started to evolve into more integrated and multidisciplinary approaches, which are centered on the concepts of sustainability and multifunctionality [6, 10, 11].

A more recent planning approach is GI and it is thought to be able to ensure the multifunctionality of different land uses and provide sustainable benefits to nature, biodiversity and people from available land in and around urban environments. However, there is still need for a more robust decision-making structure and feasible planning approach as well as a measurable and traceable tool to planning GI in order to achieve these goals.

This chapter reviews and discusses the literature on landscape ecology applications in landscape planning with an emphasis on sustainability in urban environments. The chapter starts with urbanisation as an issue and explains how it leads to fragmentation and the loss of connectivity. After giving a brief overview of issues related to fragmentation, it moves on to the relationship between urbanisation and sustainability. Thereafter, it introduces different ways in which networks have been developed in ecology and planning to mitigate the adverse effects of fragmentation by enhancing landscape connectivity.

2. Urbanisation and sustainability

2.1. Urbanisation, fragmentation and connectivity

Urbanisation can be defined as a dynamic process, where the land is mainly modified with an extension of the urbanised area and/or increased population [12–14]. While different social processes are regarded as the main drivers of urbanisation (i.e., population growth and employment opportunities), the process of urbanisation itself affects social, economic and political life [14, 15].

In general, urbanisation is thought to have adverse effects on the nature, biodiversity, the quality of life of people as well as the functioning of local and global ecosystems [16]. Since the built-up areas cover a large proportion of the land surface in urban environments, they are generally thought to be more disturbed and degraded compared to rural areas [16, 17].

However, it has been claimed that the process of urbanisation may also provide favourable conditions for biodiversity as it creates and supports a variety of species because of the diversity of habitats included in urban environments [12, 18, 19]. This is exemplified in the work undertaken by Gaston et al. [20] who demonstrated that domestic gardens in Sheffield

contain a large amount of biodiversity. Also, Savard et al. [21] drew our attention to some other benefits of urban ecosystems to people, species and the other aspects of biodiversity (e.g., population structure and genetic diversity). This is evident in the case of the cultivation of rare plants in urban areas, which may attract species that are dependent on those plants.

On the other hand, changes in the existing land uses/covers and fragmentation have assumed to be the most important environmental issues associated with the process of urbanisation [7, 22–24]. The term fragmentation reflects both a status and process. As a status, fragmentation can be defined as the degree of isolation of previously connected landscape components [25, 26]. As a process, it implies a dynamic process of structural and functional changes in a landscape where a continuous habitat type is split into separated patches with different sizes, shapes and functions [9, 10, 27].

Bennett [23, 24] summarises the major effects of fragmentation under structural changes in the landscapes and adverse effects on wildlife. With regard to its effects on landscape structure, fragmentation causes the loss and/or degradation of valuable habitats with an increasing isolation – or in other words the loss of connectivity [9, 23, 24, 28–30]. Recent evidence suggests that larger habitats can support a wide diversity of animal and plant species [31–33]. Accordingly, the loss or reduction of habitats also means a dramatic reduction in biodiversity, where some species become rare or extinct depending on their habitat requirements [9, 10, 32]. Therefore, the maintenance of connectivity has been regarded as a worldwide concern to mitigate the detrimental effects of fragmentation as well as the conservation of the nature and biodiversity.

The concept of connectivity stems from the relationships between the spatial structure and functioning of landscape and means “the degree to which a landscape facilitates or impedes movement of organisms among habitat patches” [4, 35, 36]. As one of the fundamental properties of landscapes, connectivity has been considered as “a measure of the ability of organisms to move among suitable habitat patches” [4, 30, 37].

According to another definition provided by Ahern [38], connectivity is “a spatial characteristic of systems which enables and supports the occurrence of specific processes and functions, through adjacency, proximity or functional linkage and connection”. In this regard, the concept of connectivity encompasses the structural and functional aspects of a landscape. While structural connectivity refers to the degree to which habitat patches are physically/structurally linked to each other [23, 24, 39], functional connectivity denotes the measure of species’ ability to move between habitat patches and does not necessarily require physical connections between habitat patches [19, 40, 41]. Functional connectivity, therefore, depends on the behavioural responses of organisms to the spatial structure of landscapes [39, 42, 43].

2.2. Urbanisation and sustainability

The relationship between urbanisation and sustainability largely depends on their dynamic interactions and interdependencies with environmental, societal and economic processes [44]. In urban areas, natural habitats and biodiversity have been subjected to intense human disturbances, and so urban environments and their surroundings have been the focus of

conservation efforts [45]. In conjunction with the increased concerns for the nature and biodiversity, sustainability has become a central issue in urban areas, as a response to the growing concern for the quality of the natural environment as well as the social and economic life in the early nineteenth century [46, 47].

The concept of sustainable development is formally defined for the first time in the Brundtland Report (Our Common Future) as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [48]. The concept of sustainable development seeks to achieve a dynamic and long-term balance between socioeconomic (e.g., well-being and equity of people) and environmental systems (e.g., protection and maintenance of the nature and biodiversity) [49]. As suggested by Selman [10], the landscape itself provides an arena in which this balance might be provided and maintained.

With regard to sustainability in landscapes, it is claimed that a generally accepted definition of landscape sustainability is lacking or it is generally defined in different contexts [49, 50]. While some researchers used the Brundtland Report as the source of definition with an emphasis on the maintenance of ecological integrity and basic human needs [27, 51], some highlighted the importance of natural capital and ecosystem services [52, 53], while others considered the localisation and self-regenerative capacity as the essential property of sustainability in landscapes [54]. However, in broad terms, landscape sustainability is defined as “the capacity of a landscape to consistently provide long-term, landscape-specific ecosystem services essential for maintaining and improving human wellbeing in a regional context and despite environmental and sociocultural changes” [49].

As with the three pillars of sustainability (environment, society and economy), landscape sustainability has been described on the basis of a variety of dimensions. Selman [50] draws attention to the five dimensions of landscape sustainability – i.e., environmental, economic, social, political and aesthetic sustainability. Likewise, Musacchio [55] describes six dimensions of landscape sustainability: environment, economy, equity, aesthetics, experience and ethics.

Selman [20] claims that environmental sustainability stems from landscape ecology as a response to the fragmentation of landscapes with an emphasis on the importance of landscape multi-functionality, ecosystem services and/or resilience. First of all, a sustainable landscape should maintain and improve landscape connectivity to facilitate species' life cycles as well as sustaining healthy and viable populations through a biodiverse network of habitats [50, 55, 56]. It should also be able to support other functions, provide a variety of ecosystem services to people, biodiversity and nature, besides its ability to achieve a state of relative stability [50, 57]. Another dimension of a sustainable landscape, the economic sustainability, draws attention to the importance of a “virtuous circle” in which the endogenous economic vitality of a local landscape maintains and supports environmental production practices (i.e., tourism, recreation, and the production of food and timber) as well as promoting landscape quality and the quality of life [10, 55, 58]. The social sustainability of a landscape, on the other hand, refers to opportunities for public participation in decision-making processes, inclusivity and equity in access, equal right to benefit from the use of

resources, social inclusion and community cohesion [50, 58]. The political aspect of landscape sustainability focuses on an effective governance structure, where the planning, protection and management of different landscape elements are put in place on common grounds for both the public and private sectors [50]. Finally, the aesthetic sustainability of a landscape relates to the visual amenity and healthy functioning of the landscape [50, 55].

In view of all that has been mentioned so far, we can clearly see that a sustainable landscape is a multidimensional and dynamic system in which every component is crucial for providing multi-functionality, supporting the essential ecosystem services, benefiting the health and well-being of people as well as meeting the different needs of people in urban environments.

3. Landscape ecology and landscape planning

While a variety of definitions of landscape ecology have been proposed, one of the first people to use landscape ecology was Carl Troll [59], who integrated the different concepts of geography and ecology into a new inter-disciplinary research area [60, 61]. Defined as “the study of structure, function and change in a heterogeneous land area composed of interacting ecosystems” [62, 63], landscape ecology encompasses three main characteristics of landscapes: structure, function and change.

Landscape structure is the mosaic of different geographical units (ecosystems, etc.) and is characterised by the amount and occurrence of different units (composition) as well as their spatial distribution and arrangement in the landscape (configuration) [64–68]. Landscape function refers to the interaction between spatial components of landscapes (flow of matter, energy and organisms) and landscape change expresses alterations in the structure and functions of a landscape over time [27, 62, 69]. These three characteristics of landscapes are closely associated with each other and their relationships constitute the past, current and future landscapes [64, 70, 71].

Landscape ecology not only helps researchers to investigate the spatial structure and functions of changing landscapes, but it also can help to identify the origin of changes and the interactions between spatial structure, function and change of a landscape in order to find the most appropriate options for decision making [62, 63, 72–75]. Hence, it is clear that the science of landscape ecology provides valuable insights into how short and long term landscape planning processes can improve the quality of life and achieve sustainability in urban environments [74, 76].

According to a definition provided by the Landscape Institute [77], landscape planning is “the development and application of strategies, policies and plans to create successful environments, in both urban and rural settings, for the benefit of current and future generations”. This definition refers to a formal process of decision making and technical/spatial planning activity built upon the assessment of physical, natural and cultural resources, where the main concern is the enhancement, restoration and/or creation of landscapes [10, 38, 78].

As mentioned earlier, urbanisation has been regarded as one of the main drivers of the change in landscape structure and function. As being one of the fundamental functions of a landscape, connectivity enables the movement of organisms through landscapes as well as sustaining other functional processes in a landscape [10]. Therefore, the crucial role of landscape connectivity for the conservation of nature and biodiversity has been emphasised by researchers to reduce the adverse effects of urbanisation, in particular the fragmentation and isolation of habitats [4, 32, 34, 69, 79, 80].

While planning is regarded as a key tool to deliver sustainable development [10], the need for multi-disciplinary and more integrated approaches to nature conservation and landscape planning has been highlighted [6]. Within this context, in order to mitigate the effects of fragmentation and to conserve nature and biodiversity in urban areas, different spatial planning approaches and strategies have been integrated into landscape planning and ecology, i.e., habitat creation or preservation that produces more connected patches or networks [7, 23, 26].

The growing recognition of connected systems was reflected in planning strategies such as greenbelts and linked park systems since the early nineteenth century. Thereafter a variety of approaches have been developed throughout the world with regard to the connected systems of green spaces in urban areas (i.e., ecological/green networks) [1, 2, 6, 38, 81, 82].

Even though each of these network approaches shares a great deal of common ground in terms of their main idea and structural properties, they typically differ from each other in their intended aims and functions that the networks will deliver [6]. While there has been a consensus on the main benefits of different network approaches for nature, biodiversity and people [4, 5, 83–85], there is a degree of uncertainty around the terminology on these approaches [3]. In this regard, it is necessary to clarify exactly what is meant by different network concepts and approaches in the literature. The next section therefore looks at the definition, the underlying rationale and the development of different networks being planned and managed in urban areas.

3.1. Linked park systems, green belts and greenways

The idea of greenways originates in the concept of parkways, the linear system of green and open spaces in urban areas, which was first developed by Frederick Law Olmsted in the nineteenth century [6, 86, 87]. Frederick Law Olmsted, the founder of the profession of landscape architecture in the USA, proposed two important plans for Brooklyn and Boston in order to connect urban parks and the surrounding areas as linear park systems. With a width between 65 and 150 m, these parkways aimed to deliver aesthetic and recreational functions for the benefit and use of people [6, 88, 89].

As the first greenway approach in the USA, the Boston Park System – or in other words the “Emerald Necklace” – was an attempt to integrate urban and suburban areas to increase the functioning of these areas [89–91]. On the other hand, in the same period in the UK, the concept of the “green belt” was first introduced by Ebenezer Howard, in his book *Garden Cities of Tomorrow* [92, 93]. Howard [94] claimed that if green and open spaces were located in close

proximity to residential areas, they would contribute significantly to the physical and mental health of residents as well as their well-being.

The underlying idea of green belts was separating urban and rural environments from each other by designating some of the land around the inner cities as green to regulate urban sprawl and protect the countryside beyond the urban areas [6, 10, 93]. The fundamental difference between the traditional linked park systems and green belts is in their main functions. While the concept of parkways is built upon green corridors from and to the urban parks which are surrounded by trees (linking function), the concept of green belts is largely based on the idea of controlling urban growth by separating urban and rural areas with a buffer of undeveloped land (separating function) [6, 92]. Conversely, according to Kühn [95], in the future, green belts might behave as complementary zones between different urban areas by linking them in a polycentric city region [95]. Within this framework, being located in the urban fringe, green belts have the potential of providing a multifunctional and dynamic environment where there is a wide variety of low-density economic activities and a diversity of wildlife [96, 97].

At that time, the town planner Patrick Abercrombie developed another pioneering approach to planning and implementing a park system for Sheffield: the Sheffield Civic Survey and Development Plan. In this comprehensive city plan, Abercrombie [98] proposed a park system where all the individual open spaces (e.g., existing and new parks, playgrounds, accessible moorlands and waterwork properties) were linked to each other with tree-planted avenues.

According to Abercrombie [98], the success of a systematic provision of open spaces in urban areas is dependent on the area, use and distribution of open spaces. Accordingly, the following planning principles underpinned the Abercrombie's city plan:

- The area of different open spaces must be proportional to the whole extent of the city.
- The different uses and functions of open spaces should be determined by their user groups.
- Open spaces must be distributed throughout the city, in particular where it is appropriate and required. Therefore, planners should take into account the travelling distance to open spaces. Additionally, depending on the use of open spaces, certain types of parks should be located evenly throughout the city, whereas some of them must be placed in the city centre or distributed irregularly [98].

The underlying principle employed in Abercrombie's plan represented an emerging theoretical basis for the linked park systems, where it was suggested that all the green and open spaces should be located close to the centres of population it serves. Additionally, Winkler [99] claims that this strategic plan, grounded on an in-depth analysis process, has a crucial role in the development of Sheffield. Perhaps most importantly, Abercrombie's plan revealed the actual structure of Sheffield at that time, offering a complete framework for green and open spaces throughout the city and towards the Peak District National Park as well as making clear connections between green and open spaces and the centres of population [99].

Following these pioneering planning strategies, the concept of greenways has become a common landscape planning approach all over the world. Little [100] defined a greenway as the following:

- “A linear open space established along either a natural corridor, such as a riverfront, stream valley, or ridgeline, or overland along a railroad right-of way converted to recreational use, a canal, scenic road, or other route,
- Any natural or landscaped course for pedestrian or bicycle passage,
- An open-space connector linking parks, nature reserves, cultural features, or historic sites with each other and with populated areas,
- Locally, certain strips or linear parks designated as parkway or green belt”.

Additionally, according to a definition provided by Ahern [3], greenways are the “networks of land that are planned, designed and managed for multiple purposes including ecological, recreational, cultural, aesthetic, or other purposes compatible with the concept of sustainable land use”. Thereafter, a further definition is given by Ahern [38] who describes greenways as “the connected systems of protected lands that are managed for multiple uses including: nature protection, recreation, agriculture, and cultural landscape protection”.

As shown in the abovementioned definitions, the focus of greenways has been moved from a single purpose planning approach to a multifunctional network approach, which is intended to assist key ecological functions as well as supporting public enjoyment and movement in urban environments [101]. In this regard, Ahern [91] claimed that the term greenway is a generic description of various strategic landscape planning approaches and plans which embodies a multitude of concepts with the main aim of ensuring multifunctionality in urban areas.

3.2. Ecological networks

Historically, the term “ecological” was inserted into the network approaches in the Netherlands with the ecological infrastructure concept [102]. As with greenways, the concept of ecological networks has been an attempt to integrate landscape ecology into landscape planning in order to protect nature and biodiversity, manage natural resources, and also to connect people with nature conservation [6]. Even though these terms have been used interchangeably, as pointed out by Ahern [91, 103], the term ecological networks is more common in Europe, whereas the term greenways is more common in the USA. Also, while greenways initially aimed to provide access to people between urban and rural green and open spaces in the USA, ecological networks in Europe stemmed from the need to conserve species and habitats [6].

Similar to greenways, a variety of definitions have been suggested for ecological networks in the literature. Bennett [104] defined ecological networks as “the coherent systems of natural or semi-natural landscape elements configured and managed with the objective of maintaining or restoring ecological functions as a means of conserving biodiversity, besides providing appropriate opportunities for the sustainable use of natural resources”. According to a definition provided by Jongman and Pungetti [6], ecological networks are “the systems of nature reserves and their interconnections that make a fragmented natural system coherent, so as to support more biological diversity than in its non-connected form”.

Although differences of definitions exist, there appears to be some agreement that the concept of ecological networks is founded on the conservation of natural areas and biodiversity as well as the enhancement of the functioning of ecosystems [2, 105, 106]. In addition to these, Ignatieva et al. [107] claim that urban ecological networks are one of the most effective tools for providing physical, visual and ecological connectivity between urban areas and surrounding natural areas. Hence, the development and the integration of ecological networks into the planning system have been regarded as the spatial expression of the idea of landscape connectivity in planning activities [6].

In general terms, spatially, the structural elements of ecological networks are composed of core areas, which are usually protected by surrounding buffer zones and are linked to each other with linear corridors [1, 78, 108, 109].

As claimed by Jongman [88], core areas are generally defined on the basis of traditional nature conservation practices as the natural and seminatural areas of conservation concern or the ecologically important areas with high nature value. Thus, the primary functions of core areas are thought to be the conservation of nature and biodiversity by meeting the ecological requirements of species or ecosystems [78].

The main purpose of corridors is to enable dispersal and migration of animal and plant species by providing functional connections between core areas (e.g., ecosystems or habitats for species) [1, 78, 108]. With regards to their intended ecological functions, Bouwma et al. [109] emphasised the crucial role of the spatial arrangement, internal structure and management of corridors, where the more complex corridors can provide multiple functions for different animal and plant species. Within ecological networks, three types of corridors are defined on the basis of their spatial structures and they are landscape, linear and stepping stone corridors [1, 78]. While landscape corridors can be in various forms of linked landscape matrices, linear corridors are composed of linear landscape elements such as rivers or forest strips. Conversely, stepping stone corridors are composed of a range of small habitat patches within the landscape matrix.

Buffer zones, on the other hand, prohibit the damaging effects from external influences and maintain landscape processes within core areas and corridors by creating environmental gradients around these [78, 88, 110]. Finally, another spatial element of ecological networks mentioned by Bouwma et al. [109] includes sustainable use areas which refer to the exploitation of opportunities within the landscape mosaic for the maintenance of ecosystem services and sustainable use of natural resources [1]. Also, more intensive human uses are allowed in buffer zones and sustainable use areas only if these activities support the maintenance of ecosystem services and sustainability [78, 110].

The common goals of ecological networks are to maintain the functioning of ecosystems and to promote the sustainable use of natural resources by assisting policy sectors [6, 81]. Within this framework, ecological networks have been considered one of the most important landscape planning approaches to address issues associated with human-induced habitat depletion. The concept of ecological networks has therefore attracted the attention of conservationists and planners in Europe [111, 112]. In Europe, many international initiatives and

strategies for ecological networks have been developed [105, 113]. For example, the Pan-European Ecological Network (PEEN) is thought to be one of the most ambitious international ecological network programmes. The aims of the PEEN programme are to ensure the following:

- the conservation of a full range of ecosystems, habitats, species and landscapes of European importance,
- the maintenance of the habitats that are large enough to conserve animal and plant species,
- the promotion of sufficient opportunities for species to disperse and migrate,
- the restoration of the damaged parts of the key environmental systems, and
- the prevention of potential threats on key environmental systems [10–114].

Overall, the ecological network approach has been regarded as an important tool to maintain some level of ecological structure and function in urban areas, since they are thought to provide habitats and ecological connectivity for species and to conserve the wildlife [6]. But, as indicated by Andrian [115], the emphasis of the wildlife and nature conservation has been a major driver for the development of urban ecological networks and there is still a need for integrating social and cultural values into ecological networks.

3.3. Green networks

The green network concept has been inserted into urban planning practices, principally based on the idea of ecological networks [116]. Accordingly, the ecological and green network concepts have been used synonymously. However, the transition from ecological networks to green networks has created a noticeable shift in the spatial planning of nature and human dimensions. In other words, while the focus of the ecological network concept was on the conservation of species and habitats, the concept of green networks has brought the needs of species and humans together under the same roof [6, 82]. Moreover, the concept of green networks recognises the crucial role of green and open spaces and the linkages between them to support and improve sustainable development and also to enhance the functioning of urban environments [82]. Here, it is also important to note that the multiple benefits (social, economic, health and environmental) of urban green and open spaces have already been recognised by researchers, planners and decision-makers [84, 117–121].

Barker [122] defined green networks as “natural, or permanently vegetated, physically connected spaces situated in areas otherwise built-up or used for intensive agriculture, industrial purposes or other intrusive human activities”. Additionally, the term green network was used by Bennett [104] to refer to a “spatial planning tool for the purpose of balancing and integrating land uses”. Thus, the concept of green networks has been seen as a multifunctional urban planning approach, in which the value and importance of natural, seminatural habitats and human-dominated habitats (e.g., urban green and open spaces) are appreciated to deliver benefits both for people and the environment.

Regarding the requirements of people in urban environments, a recent study by Scotland and Northern Ireland for Environmental Research claimed that green networks are capable of increasing the number of people visiting urban green spaces and the countryside by providing a safe environment for people to move across [85, 123]. Furthermore, the green network approach goes beyond the limited vision of developing individual green spaces in urban areas just for recreational and visual purposes and focuses on the functionally connected systems of formal and informal green and open spaces [122, 124].

According to Forest Research [82], the concept of green networks takes into account multiple functions offered by green spaces as well as their ability to support the movement of people and species by the interconnections between them. Within this framework, the differences between individual green and open spaces and a green network have been explained according to their functions and spatial configurations. While green spaces refer to publicly accessible individual green areas in urban environments, green networks reflect a strategically identified and functional system of green spaces for the benefit of people, habitats and biodiversity [82, 125].

As well as these important features of green networks, Barker [122] suggested that one of the major benefits of green networks is their ability to provide connections between urban and rural landscapes. Therefore, green networks are said to be able to fulfil the requirements of wildlife, support ecological processes and meet the recreational, visual and social needs of people. In most countries, even though green networks have been primarily developed for their benefits to nature and biodiversity, they also serve multiple uses and functions such as meeting the ecological requirements of species and providing recreational facilities to people [122]. For example, in Sheffield, reasons for conserving and improving a green network for people and wildlife are defined as the following:

- to increase and support biodiversity in Sheffield and the surrounding areas,
- to allow the dispersal and genetic exchange of species throughout the city,
- to reduce the adverse effects of fragmentation and isolation,
- to control and support a sustainable drainage system,
- to encourage the movement of people by increasing the access to open and green spaces, and countryside,
- to improve the well-being and health of people, and
- to improve the general character of the city as an attractive and healthy place [126].

From a theoretical point of view, it is obvious that the intended functions of green networks are broadly compatible with the main functions of ecological networks, which aim to support and enhance the movement of animal and plant species. Besides maintaining and enhancing urban biodiversity and nature, the green network approach also provides appropriate opportunities for the sustainable use of natural resources, and so is regarded as one of the fundamental components of a more sustainable urban environment [82]. To conclude, the

green network approach has been inserted into the planning and management strategies as a broad concept to achieve multifunctionality for biodiversity and people in urban areas.

3.4. Green Infrastructure

As a more recent approach, the GI concept takes its theoretical and conceptual background from the abovementioned network approaches to provide multiple benefits for biodiversity, nature and people within an urban environment [127, 128]. For this reason, we can claim that the GI concept is not a new idea in landscape planning and management [129]. Accordingly, it can be suggested that the concept of GI is grounded on the recognition of the crucial role of green networks in the wider landscape to provide essential services, functions and resources. In this context, Rouse and Bunster [130] claim that the previous plans of green and open spaces (e.g., greenways) have been increasingly adapted as GI plans to provide environmental, economic and social benefits in urban environments.

GI is defined by Benedict and McMahon [127] as “an interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas; greenways, parks and other conservation lands; working farms, ranches and forests; and wilderness and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to the health and quality of life for communities and people”. In addition, according to Natural England [131], GI is “the network of multifunctional open spaces, waterways, trees and woodlands, parklands and open countryside within and between our cities, towns and villages”. In an urban context, the Natural Environment White Paper defined GI as “the living network of green spaces, water and other environmental features in both urban and rural areas. It is often used in an urban context to cover benefits provided by trees, parks, gardens, road verges, allotments, cemeteries, woodlands, rivers and wetlands” [132]. Furthermore, Natural England [133] suggested that GI is “a strategically planned and delivered network comprising the broadest range of high quality green spaces and other environmental features”.

The careful wording of these definitions includes three important ideas at the heart of the GI concept: connectivity in the form of networks, multifunctionality and green components [127, 129, 134]. In spite of the emphasis on the term “green”, it is quite important to note that GI also includes the features of blue infrastructure, such as river systems, other water features and coastal environments [127, 131]. As mentioned earlier, connectivity refers to the functional linkages in a landscape for the movement of animals, plants and/or people as well as the flows of materials, nutrients and energy [30, 35, 41]. Accordingly, supporting and enhancing connectivity between (habitat) patches is an important issue for biodiversity and nature conservation, and also to support human well-being and health in GI planning [127, 134].

Moreover, taking into consideration the abovementioned definitions, it is obvious that the concept of multifunctionality is the core idea of the GI concept, since the ability of a landscape to deliver multiple benefits and functions for wildlife, nature and people has been widely recognised by decision-makers, planners and managers. Multifunctionality refers to “the potential for GI to have a range of functions to deliver a broad range of ecosystem services”

[135]. The key benefits of a GI approach are summarised by Forest Research [136] as the following:

- mitigating and adapting to the effects of climate change,
- supporting and promoting the health and well-being of people,
- supporting economic growth and investment,
- regeneration of previously developed, derelict, underused and neglected (brown fields) lands,
- protecting, supporting and improving wildlife and habitats, and
- enhancing social inclusion and creating community cohesion.

The Landscape Institute [137] claims that a strategically planned and managed GI approach may provide enhanced multifunctions in comparison with the sum of individual green and open spaces in an urban area. The concept of multifunctionality can be fitted into the planning of individual green and open spaces as well as routes but we can achieve a fully multifunctional GI network when these individual sites and their connections are taken together [10]. In this respect, it is important to note that multifunctionality in a landscape is characterised by a high level of complexity, where different functions occur at the same time and interact with each other [138].

Consisting of natural, seminatural and man-made ecological systems altogether in a system, a GI forms a multifunctional network within and around urban areas [139]. Hence, the planning and management of a GI approach should take into account its capacity to deliver multiple ecological services, address the requirements of people and enhance the spatial character and quality of landscapes in urban environments [96, 131, 133]. Accordingly, a GI approach also requires involvement of a variety of stakeholders (e.g., planning authorities, policy makers, conservationists and the general public) in order to meet its intended functions and benefits that we expect them to provide [5, 140, 141].

In brief, the GI is a more promising and comprehensive planning approach to develop a coherent system of green and open spaces which serve multiple purposes and provide multifunctionality in urban areas [142].

4. Discussions and conclusions

The objective of this chapter was to provide a deeper understanding of the context and evolution of different approaches to planning and designing urban networks. While, during their early stages, different approaches had their own planning aims and strategies to define networks spatially, subsequently, their general concerns about nature, wildlife and people have become more aligned [6].

In early network planning practices, although natural and seminatural habitats were connected to each other for the benefit and use of wildlife, the linkages between urban green and open

spaces were more concerned with people's use and enjoyment of nature. However, in urban environments, it is hard to develop a network which focuses only on the conservation of nature and biodiversity or the benefit of people [3]. In many cases it is not appropriate to apply such an approach, since we cannot ignore the interactions between nature and people in urban environments. In this context, there has been a shift from single purpose planning approaches to more comprehensive and integrative planning approaches in order to deliver multifunctionality in urban environments [10, 80].

All network approaches recognise the importance of functional connections for biodiversity and people in an increasingly fragmented urban environment. Accordingly, the common characteristics of the different network approaches are their spatial configuration and focus on connectivity. With regard to their spatial configuration in landscapes, all networks benefit from a linear structure in which different habitats and green and open spaces are included and connected. In relation to that, there is evidence for the benefits of networks to wildlife and biodiversity and people. The wider benefits to wildlife and biodiversity include facilitating the dispersal, genetic exchange and variability of many animal and plant species; increasing species' resilience to the environmental changes, predators and human disturbances and supporting the essential ecosystem services [2, 4, 83]. The benefits of networks to people, on the other hand, include supporting the health and well-being of people and enhancing community spirit [5, 84, 85, 136].

However, our understanding of the underlying science and the ways of planning, designing and managing networks in urban landscapes is still developing. Accordingly, one of the most important obstacles to enhance connectivity, maintain biodiversity and support human well-being through the planning of networks has been the gap between their intended aims and actual outcomes in urban environments.

A comprehensive network planning approach requires the following considerations in order to achieve sustainability and multifunctionality in urban environments. Sustainability is a natural characteristic of any planning activity. Accordingly, the spatial planning of networks requires the investigation and integration of ecological, societal and economic aspects to provide multiple benefits to wildlife, nature and people. Also, detailed research is required to explore how differing land use/cover morphologies within the wider landscape matrix would support or detract from their expected functions. In addition, after the determination of areas for different functions and/or multifunctionality, their applicability should be evaluated using different tools, such as the use of multicriteria analysis as well as defining opportunities and constraints for the planning decisions. Moreover, the planning strategies for networks require cooperation between the local and regional authorities to provide and support connectivity at landscape and regional levels. It is also important to identify and cooperate with stakeholders including public/private sectors and organisations to provide and support multifunctionality and sustainability in urban environments. Finally, it is a necessity to monitor the results of networks in order to measure and ensure the success of the network plans as well as identifying any changes and modifications to these plans.

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